Formation of Optimal Thermoenvironment in Cubicles of Cold Cowshed
Optimāla temperatūras režīma nodrošināšana, govis turot nesiltinātā kūtī

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Abstract. Assurance of a warm and convenient animal lair is particularly important in cold cowsheds. This is the most important aspect in the environment of the cow, the underestimation of which results in disorders of normal activity of the cow's organism. Investigations show that changing the temperature in cold housing cowshed from -9.4 °C to 11.6 °C, the air inside the cowshed gets by 4.3 °C warmer and by 4.2% drier than the air outside the cowshed, while the microclimate has no negative influence on animal productivity. It is established that cows' rest in cubicles is too short. In the cubicle with a rubber rug, cows lie for 8.7 hours per day, in the cubicle with straw bedding – 7.5 hours per day. In order to create better conditions for cows' rest in the experimental cowshed, the insulation of cattle lair by increasing the straw layer from 2 cm to more than 10 cm is recommended.
Key words: temperature, cubicle, cold cowshed.

Introduction

Microclimate in the cowshed is one of the most important factors that influence animal productivity. Optimal feeding does not ensure healthy and highly productive animals of the best breeds if microclimatic conditions in the cowshed are unfavorable. Productivity of the cows that are kept in warm and humid cowsheds decreases by 17-18% (Burmeister, 1988; Пляценко, Хохлова, 1976). Having increased ventilation intensity in the cowshed and decreased temperature to -5 °C, the air is drier and cleaner and animals feel significantly better. At the same time their resistance to diseases increases and more natural conditions are created (Johannesson, 2000). When air temperature inside the cowshed subsides below -10 °C, a bigger amount of fodder is used, however, but it is better used by the animal's organism. In the case of a dry and draught-free cowshed and a warm, clean and comfortable lair, the cows can survive very low temperatures (Keck, Zähner, 2004). In comparison with other animals, cattle is less sensitive to low temperatures as constant impact of cold strengthens them, improves thermoinsulation characteristics of tissues, i.e. the fur becomes thicker and accumulation of adipose tissue in hypodermic-grease part intensifies. However, the danger of negative impact remains, especially, if the animal lies on a cold floor. If the temperature of animal's body falls one degree below the critical temperature, the metabolism intensifies by 2-3%, fodder consumption increases by 15-30%, but productivity decreases by 10-20% (Пляценко, Хохлова, 1976).

In Lithuania, cows have been kept in cold cowsheds of light constructions since 1998. Construction of such cowsheds requires significantly less building materials, therefore, investments and cost of production decrease. Assurance of dry, warm and clean animal lair is particularly important in these cowsheds. This is the most important aspect in the environment of the cow, the underestimation of which results in disorders of normal activity of a cow's organism. Energetic balance of the animal changes, energy losses to the environment increase significantly. At low temperatures of air the heat exchange in the animal's organism intensifies because of quicker metabolism. This requires additional source of energy, which can be received together with fodder. When temperature of the environment is 20 ^{0}C, a cow of an average mass (600 kg) and average productivity (5000 l of milk per year) exudes 0.86-0.97 kWh of heat. A total of 8-9 fodder units have to be used to produce the mentioned amount of heat. In order to decrease fodder consumption and increase its utility coefficient, an optimal temperature regime in the place of cows' rest – cubicle – has to be created (Пляценко, Хохлова, 1976). Therefore, the floor of the cubicle is covered with rubber rugs, mattresses, sand, straw, etc. Their thermoinsulation characteristics are of primary importance. Sudden and short-term temperature fluctuations have the strongest negative impact on cows (highly productive cows in particular). They often cause various cow diseases. Disturbance of normal functions of animal's organism under the influence of temperature fluctuations is one of the main reasons that cause various cow diseases. Therefore, maintenance of optimal air temperature in animal lairs, assur-

ance of optimal welfare and comfort are of significant importance (Wandel, 1998).

The problem of decreasing the negative impact of low temperatures inside the cowshed on the animal's organism arises. Analysis of numerous researches, carried out by foreign scientists (Stolpe, 1985; Баротфи, 1988; Wandel, Jungbluth, 1997; Eichhorn, 1999; Rorbech, 2001), has revealed several ways to solve this problem:

- fodder norms should be increased;
- animals should be hardened by taking them for a walk outside in winter;
- conditions for an optimal temperature regime in the animal lair should be created.

The latter method has been analyzed and investigated in a new cold housing cowshed under climatic conditions of Lithuania.

The object of investigations: a place for animal's rest – a cubicle in a cold cowshed.

The aim of investigations: analysis of the change of thermal parameters in cubicles of cold cowshed and provision of measures for their improvement.

Materials and Methods

The investigations were carried out in a cowshed of a cold cubicle type for 200 cows. The lower part of the cowshed wall was made of concrete blocks. The upper part of the wall was made of single boards with 2.0 cm cracks for the fresh air from outside. The roof was covered with slate; standard blocks were used to join the constructions of the cowshed. Average coefficient of wall and roof heat transmission – 4.9 W $m^{-2} K^{-1}$. Length of a cowshed – 72 m, width – 21 m. Fresh air got into the cowshed through cracks between the wall's boards, the polluted air was removed through the ridge crack of 0.6 m. Total area of air inlet cracks – 17 m^2, of outlet crack – 43 m^2. Cows were kept in a loose housing system, in cubicles. All cubicles, except four, were littered with straw. These four cubicles were covered with special rubber rugs. Different cubicles of two types – littered with straw and covered with rubber rugs – were chosen for the investigations. Thickness of the rubber rug was 3 cm, thickness of straw cover – 2 cm. Parameters of the cubicles, used for experimental investigations, were as follows: length – 2.20 m; width – 1.24 m; height above the manure path – 0.20 m.

The investigations were aimed at establishing the following:

- temperature of cubicle floor under the 2 cm straw layer and under the 3 cm rubber rug;
- air temperature inside and outside the cowshed, relative humidity.

The following modern devices were used for the investigations: computer-controlled device "Almemo, Drager Pac III". Temperature and moisture sensor TRACER was for corresponding intervals of measurement. Limits of the cubicle's floor temperature measurement were from -10 °C to +30 °C, and limits of the outside air temperature and relative humidity measurement were from -20 °C to +60°C and from 0% to 100%. In the course of the investigations, the floor temperature was registered every 5 min, the air temperature inside the cowshed and relative humidity were measured at a 2 m height above the floor every 1 hour, outside air temperature and relative humidity on the north side of the cowshed were measured every 1 hour. The scheme of sensors' distribution in the cubicle is presented in Figure 1. Sensors' readings were registered for 118 days without interruption. The investigations were carried out during the cold period of 2002-2003.

According to the change of temperature in the cubicle floor, it was determined how much time per day a cow spends therein. The most intensive increase of temperature is when a cow is lying down; an intensive decrease of temperature is when a cow gets up. When

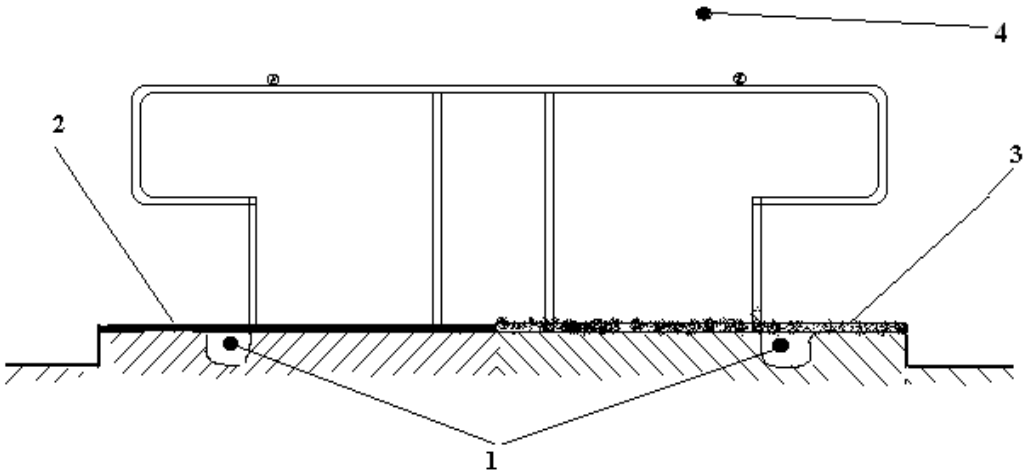

Fig. 1. Cross-section of the cubicle in experimental cowshed: 1 – temperature sensors in the floor of the cubicle; 2 – cubicle covered with rubber rug; 3 – cubicle with straw litter; 4 – temperature-moisture sensor above the cubicle.

a cow is lying down, the increase of temperature is recorded by sensors according to parameter τ_1 which depends on thermal characteristics of the flooring. When a cow gets up, the decrease of temperature is recorded by sensors according to parameter τ_2. Provided that thermal conditions of flooring do not change when a cow is lying down on it, $\tau_1 = \tau_2$, and thermal characteristics of flooring are not estimated when defining the intervals of temperature increase and decrease (the duration of cow's lying down).

Results and Discussion

A cubicle is a very important place, where an animal can get maximal rest without experiencing any traumas or stresses. Various floorings and litter have the strongest influence on the comfort of the cubicle. The cubicle that meets the main requirements, should be clean, dry, soft, warm (not heat conductive), and comfortable. In a warm cubicle cows feel safe and the risk of disease decreases.

During the investigations, average daily temperature of the air inside the cowshed varied from -9.4 °C to 11.6 °C, relative humidity – from 67.4% to 95.2%, outside air temperature – from -15.2 °C to 8.3 °C (Fig. 2). In the period of the investigations, average air temperature in the cowshed was 3.7 °C, relative humidity – 81.4%, outside air temperature – -0.6 °C, and relative humidity – 85.6 %. No condensate of water steam on building constructions of the cowshed was observed, the ventilation intensity was sufficient. The microclimate had no negative impact on animal productivity. Average milk yield was 5700 kg per cow per year.

The determination of how much time per day a cow rests was based on the change of temperature in the cubicle's floor (Fig. 3). The temperature fluctuations in the floor of the cubicle were grouped and used in preliminary determination of the course of milking and feeding technologies as well as to evaluate duration of cows' rest in cubicles with different floorings (rug, straw) and comfort. A detailed analysis of floor temperatures was carried out at various average day temperatures of the air inside the cowshed: -9.37 °C, -7.25 °C, -5.54 °C, -4.25 °C, -3.45 °C, -1.84 °C, +0.1 °C, +1.5 °C, +1.64 °C, +2.56 °C, +3.78 °C, +4.21 °C, +5.04 °C, +6.5 °C, +7.33 °C, +8.4 °C, +8.9 °C, and +10.2 °C. These temperatures were chosen for more comprehensive generalization of temperature changes in the floor of the cubicle.

According to the opinion of Danish scientists (Johannesson, 2000), at 2 a.m. most of the cows, i.e. about 90%, rest if the lair is comfortable. This tendency was also observed in the experimental cowshed where the investigations were carried out. In the morning (at

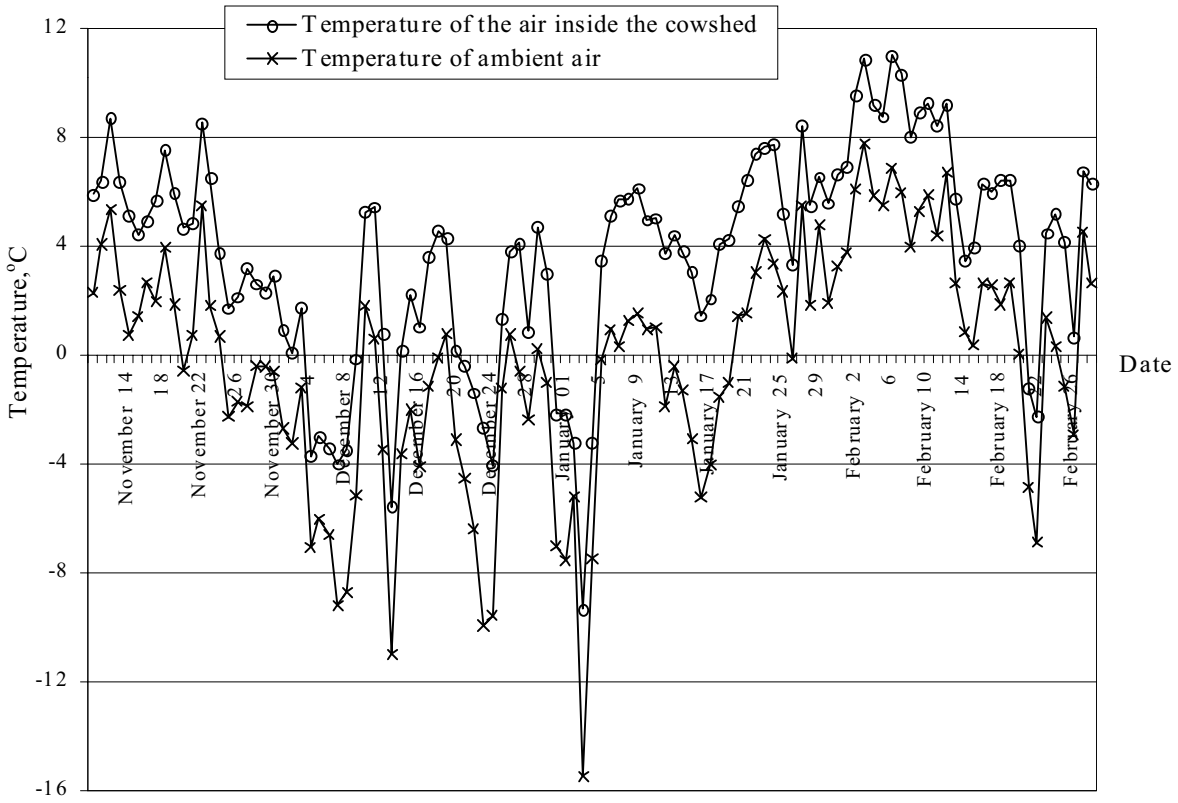

Fig. 2. The change of inside and ambient air parameters.

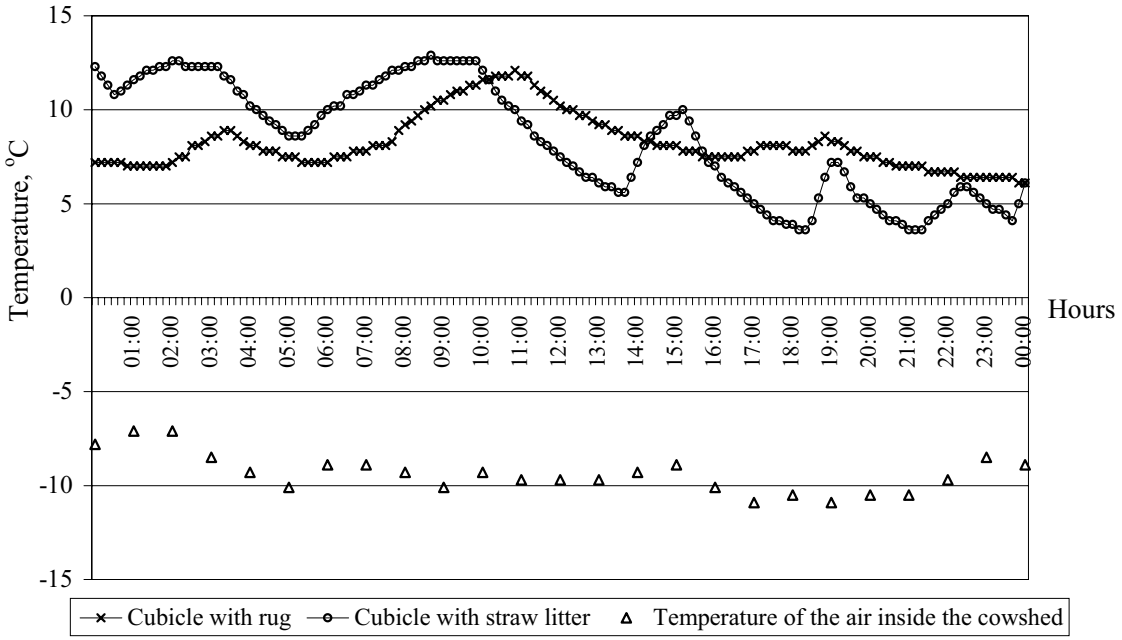

Fig. 3. The change of temperature in the cowshed and under flooring in the cubicle per day (the average of cowshed air temperature is -9.4 °C).

8 a.m.) when fodder was brought in cows did not hurry to eat. This led to the conclusion that they were full and had received sufficient feeding. At the time of milking in the morning (at 3.30 a.m.) and in the afternoon (at 3.30 p.m.), all cows got up from their lairs and went to the milking room.

For up to 50-60% of time per day cattle should lie (Jungbluth et al., 2005). The longer a cow lies, the higher productivity can be expected. Productivity increase is related to a longer period of rumination and flowing of blood to udder. During the investigations in the experimental cowshed, it was established that at inside air change from -9.4 °C to 10.2 °C, cows rested in the cubicle with rubber rug for 6.1-10.2 hours per day, and in

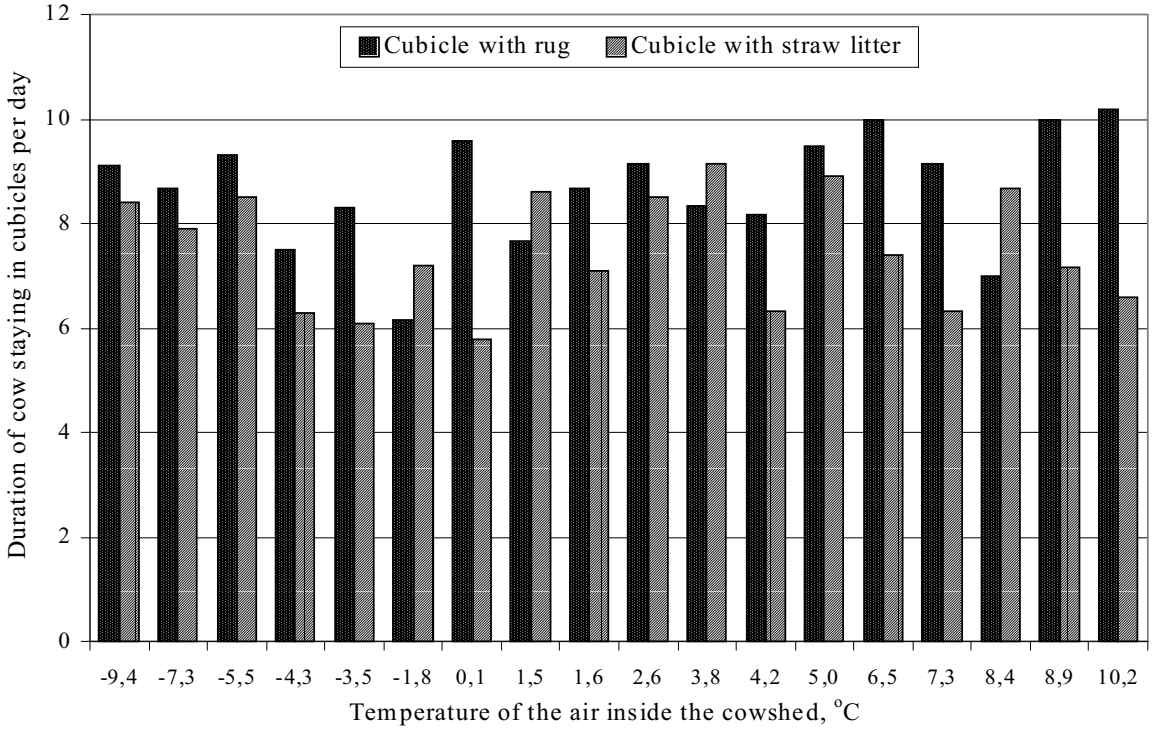

Fig. 4. The duration of cow staying in cubicles per day at different temperatures of the air inside the cowshed.

the cubicle with straw litter – for 5.8-9.2 hours per day. Average duration of lying on rubber rug per day was 8.7 hours, on straw – 7.5 hours (Fig. 4). No dependency of the duration of cow lying on the air temperature was determined. Nevertheless, it was noticed that in case of air temperature fall below zero inside the cowshed, cows' rest time in cubicles was shorter. This was most noticeable in the cubicle with straw litter. Scientists have established that only in comfortable cubicles cows lie approximately for 11.0 hours per day (Nilsson, 1988). If the duration of lying increases up to 11.5 hours, the time spent by a cow at feeding-rack prolongs from 5.08 to 5.54 hours. This proves that the cows that have better rest also have increased feeding activity and productivity. Therefore conveniently equipped cubicles are very important.

Average duration of the period of cow lying in the cubicle was established. In the cubicle with rubber rug a cow lies on average for 2.2 hours, in the cubicle with straw litter – for 1.9 hours. This allows concluding that cows prefer the cubicle with a rubber rug, as it is softer and warmer than the straw layer of 2 cm.

Analysis of the experience of foreign countries and generalization of experimental data suggests that improvement of cubicles enables to increase cows' productivity in the experimental cowshed. Good characteristics of cubicle's floor thermoinsulation are of primary importance. If the floor is comfortable and warm, animals will spend more time lying there. Proper selection of cubicle flooring is very important. Despite the positive properties of straw litter, interest in other types of cubicle flooring has increased in recent years because of the reduction of labor expenditure for straw preparation and storage. Therefore, use of straw for litter has decreased because of the high costs of straw preparation, processing, and storage. Farmers often decrease the amount of straw in cubicles for the purpose of better results and lower costs. It is useful from economical point of view; however, due to big heat losses through the floor the temperature of animal body may decrease by several degrees. This is the problem that should be considered.

On the 50th day after coupling, a standing cow which weighs 700 kg and yields 20 kg of milk per day, releases the free heat flow to the environment of the density of 215 W m^{-2} (Sallvik, 1998), when the ambient temperature is -9.4 °C. After a cow has lain down, its contact area with ambient air decreases, heat release by convection and radiation decrease, but heat release through floor by conductivity occurs. The release of free heat does not increase and a cow avoids stress, unless heat flow through floor is bigger than 215 W m^{-2} after the animal has lain down. In the theoretical analysis of thermal characteristics of floorings the following conditions are assumed: heat exchange between a cow and environment is constant, and the temperature of a cow body surface (skin) is 36 °C. Average minimal temperature under the flooring is 5.6 °C (this temperature was determined during the experiment). Using the methodology suggested by Ludo Van Caenegem (Caenegem, Wechsler, 2000), following calculation results were obtained: density of heat flow through a 10 cm concrete layer is 547 W m^{-2}, through a 2 cm straw layer – 456 W m^{-2}, whereas through rubber rug – 95 W m^{-2}. The heat flow through the floor does not exceed 215 W m^{-2}, if the straw layer is thicker than 4.5 cm. Therefore it is not enough to spread a straw layer of 2 cm in the cubicle as the heat flow through the floor becomes very big, i.e. after a cow has lain down, the release of free heat increases. This is one of the reasons why a cow lies too shortly in such a cubicle. To reach the warmth of the cubicle floor equal to that of a rubber rug, a sand layer of 17 cm or a straw layer of 9.6 cm should be spread. Therefore in the experimental cowshed the layer of straw on the floor should not be less than 10 cm (after a cow has lain down, the thickness of the layer decreases to 3.4-4 cm).

Conclusions

1. The following behavior of animals in the cubicles of cold cowshed has been established on the basis of temperature changes in the floor:
– cows' staying in the cubicles is too short. In the cubicle with rubber rug a cow rests on average for 8.7 hours per day, in the cubicle with straw layer of 2 cm – for 7.5 hours. On average a cow should lie for 12 hours per day;
– in the cubicle with rubber rug the average duration of a cow's lying is 2.2 hours, while in the cubicle with straw litter – 1.9 hours. A cow gets up too often, which allows concluding that the cubicle is not convenient.

2. The straw layer of 2 cm is too thin for the cubicle as release of free heat increases when a cow is lying down. The release of heat to the environment does not increase if the thickness of straw layer is more than 4.5 cm. To decrease the animal energy losses through the floor and to reach the warmth of floor equal to that of a rubber rug, the straw bedding of at least 10 cm is required.

3. In the cold cowshed, at air temperature fluctuations from -9.4 °C to 11.6 °C, relative humidity varies from 67.4% to 95.2%. In the cowshed, the air is on average by 4.3 °C warmer and by 4.2% drier than the outside air. Ventilation intensity is sufficient in the cowshed. Microclimate has no negative impact on animal productivity.

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Anotācija

Lietuvā, tāpat kā citās valstīs, paplašinās govju turēšana nesiltinātās (aukstās) vieglas konstrukcijas kūtīs, kurās īpaša nozīme ir siltai un tīrai dzīvnieku guļvietai. Tas ir pats nozīmīgākais aspekts, runājot par vidi, kurā tiek turētas govis, jo šī faktora neievērošana izraisa govs organisma normālas darbības traucējumus. Kā liecina mūsu pētījumi, nesiltinātā govju kūtī, ja iekšējās temperatūras izmaiņas ir no -9.4 līdz 11.6 °C, iekštelpu gaiss ir par 4.3 °C siltāks un par 4.2% sausāks nekā kūts ārpusē, turklāt šādam mikroklimatam nav negatīva ietekme uz dzīvnieku produktivitāti. Pamatojoties uz boksu grīdas temperatūras izmaiņu pētījumiem, noteikts, ka govīm labāk patīk boksi ar gumijas paklājiem, nekā ar 2 cm biezu salmu pakaišu kārtu. Tomēr govju gulēšanas ilgums abu veidu boksos ir pārāk mazs. Boksos ar gumijas paklāju govis guļ vidēji 8.7 h diennaktī, bet boksos ar salmu pakaišiem – 7.5 h diennaktī, lai gan tām būtu jāguļ 12 h diennaktī. Lai nodrošinātu labāku govju atpūtas mikrovidi, iesakām palielināt salmu pakaišu slāni guļvietās no 2 uz 10 cm un vairāk.